Modeling the Impact of Sexual Health Education Policies on the Spread of HIV

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1 Abstract

The human immunodeficiency virus (HIV) has been constantly studied after AIDS became an epidemic, though primarily with mathematical models. Here we use an agent-based model developed by Uri Wilensky (1997) to look at the effects of sexual education on the spread of HIV, specifically looking at the effect of condom usage and test frequency on HIV prevalence. These two parameters were selected after looking at how individual states in the United States have vastly different sexual education policies and thinking about how we could try to represent this in a model. Our results showed that greater sexual education, in the form of increased condom usage and test frequency, is associated with lower HIV prevalence and thus spread in our model's population of 300 people. While our model certainly has its limitations, these are promising results and lead us to conjecture about the benefit of national sexual education policies both in the United States, but also in countries currently more affected by the HIV/AIDS epidemic as well.

2 Background

Sexual education policies differ by state, with varying content requirements (Guttmacher Institute, 2017). Notably, Arkansas does not mandate sexual/HIV education and, when provided, the education stresses abstinence and does not cover information about condoms. On the other hand, California has the most comprehensive approach for sexual education, covering both abstinence as well as information on condoms. Work by Regine Rochelle Rucker (2005) has demonstrated that little to no knowledge about HIV is associated with infrequent condom use and an overall higher probability of risky behavior. Thus, it is highly likely that sexual/HIV education is impacting the amount of risky behavior one partakes in, with negligent education leading to more risky behavior than a comprehensive education.

Most previous efforts to model the spread of HIV have used mathematical or computer-based models. Other work by Bracher, Santow, and Cotts Watkins (2004) has modeled via microsimulation the potential impacts of condom use, focusing on women's lifetime risk of acquiring HIV in southeastern Africa. Their simulations showed that condom use has a potentially substantial impact on the spread of HIV, particularly if they are used frequently. Their result is supported by the Centers for Disease Control and Prevention (CDC) guideline that condom use is one of the most effective ways of decreasing risk of becoming infected or transmitting HIV (HIV Risk Reduction Tool, 2017). The CDC also lists test frequency as one of the most effective ways of decreasing risk, though this factor has not been as extensively studied as condom use or number of partners.

Taking into consideration that sexual/HIV education impacts involvement in risky behavior such as infrequent condom use or infrequent testing, the purpose of this study was to model the impact of sexual education policies on the spread of HIV. We investigated condom use and test frequency as indirect indicators of sexual/HIV education and focused on the percentage of the population that was infected as a dependent variable.

3 Method

We have followed the ODD (Overview Design Details) protocol designed by Grimm et al. to describe our model.

3.1 Purpose

The purpose of this model is to assess how sexual education policies, implemented through the choices of average condom use and test frequency, influence the spread of HIV in a small, isolated population. In partiular, we are comparing a population who had access to a comprehensive sexual health education program to that of a population who had not.

3.2 State variables and scales

In terms of HIV, an individual can be infected but not know it, or can be infected and know it, or can not be infected. An individual can either be in a couple and does not move as long as he/she is in a sexual relationship or the agent can be single and will then wander about.

Infected individuals who don't know they are infected are colored in blue. Colors determine the conditions of individuals. Those not infected are in green. Those in red are known to be infected.

Table 1: Parameter Description

Parameters	Description	Scale/Metrics
average-condom-use	General chance member of population uses a condom. Interpreted as x out of 10	(0–10)
average-test-frequency	Average frequency member of population will check their HIV status in a 1-year time period. - Set at 1.0, the average person will get tested for HIV about once a year. - Set at 0.2, the average individual will only get tested once every five years.	(0–2)

Table 2: Variable Description

Variables	Description	Scale/Metrics
infection-chance	if you have unprotected sex with an infected partner, you have a x percent chance of being infected	fixed at 50 percent
symptoms-show	number of weeks after infection that symptoms start to show	fixed at 4 weeks
average-commitment	how long do couples stay together on avg	fixed at 50 weeks
average-coupling-tendency	chance that the person will join a couple	fixed at 4 out of 10
CLOCK	shows how many ticks have elapsed.	1 tick = 1 week

3.3 Process overview and scheduling

The process is initialized with the "setup" command that will have 300 individuals in the environment. Two of them will be infected but won't know it. Individuals wander around unless they are in a couple. Two persons engaged in sexual relations are known as 'couples.' If one person in a couple is infected, there is a probability that the other person gets infected unless both are protected.

Single individuals keep wandering around and when they meet someone else, there is a probability that they become a couple. People in couples don't wander around and they will then stay together, holding hands, until the set commitment period ends. They will then start to wander again until they end up with someone. We are observing these individuals over a seven-year period.

We used and adapted the AIDS model from the NetLogo Models Library, adjusting it to have a more narrow focus than the original model. We used the same agents set up by Wilensky (1997), but changed some of the variables. We set specific values for the average length of commitment and the initial number of people, and fixed the likelihood that a person would join a couple. We did this in order to narrow our focus on two factors related sexual education policies.

3.4 Design concepts

Basic principles: We have assumed that on average, there is a 4 out of 10 chance that an individual in our population will join a couple (and thus be sexually active), based on a poll distributed by New York Magazine to 700 college students resulting in roughly 50% of students not engaging in any sexual activity (Kern & Noreen, 2015).

Observation: As with the original model, we measured the total percentage of the population that was infected.

3.5 Initialization

Three hundred uncoupled people are placed randomly in the grid, with 2 of them starting out as infected though unknown to them. The chance of infection is set at 50% when having unprotected sex with an infected person. We have kept the model's default value for simplicity. Symptoms are set to start showing after 4 weeks because according to the NHS Choices health website, symptoms usually appear between 2 to 6 weeks after infection. We have decided to take the average duration in this case. The length of time an individual turtle will commit to a relationship, their coupling tendency, the frequency of their condom use, and frequency of testing are set at values near those that have either been fixed or chosen. Other setup procedures were left as Wilensky (1997) wrote them.

3.6 Input

Under the given model, those in red can still get into sexual relationships but they will automatically practice safe sex. If both individuals use condom, there is no chance of getting infected but if only one of them uses a condom, infection is still possible. There is a 5% chance that a person will get a check-up once they start showing symptoms, which appear after four weeks typically. Average commitment has been fixed at 50 weeks and average coupling tendency has a 4 out of 10 chance of occurring, but during setup each individual turtle has these values determined based on a normal distribution.

3.7 Submodels

With Education: Individuals who have received a comprehensive HIV/sex education will practice safe sex 7 out of 10 times (i.e. they will have an average condom use of 7) and will have an average test frequency of 2 (i.e. they will take a test twice a year).

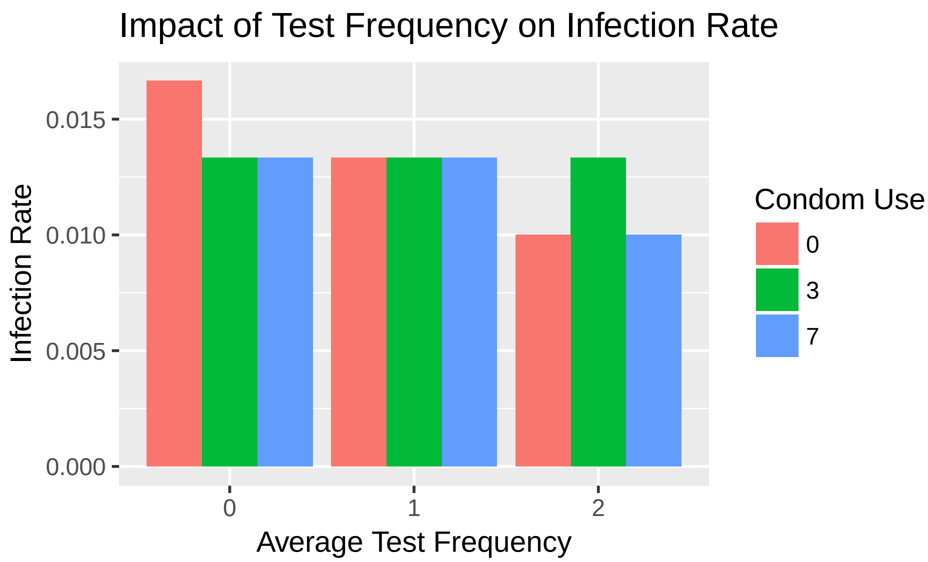
Without Education: Individuals who have not received HIV/sex education will not practice safe sex (i.e. they will have an average condom use of 0) and will not get tested.

sensing: If the infection is known, observations will know who is infected and infected individuals will practice safe sex. When infection symptoms manifest themselves, 1 in 20 times the individual will get a test done and thus identify their infected status. Individuals in couples know when their commitment period ends and break up.

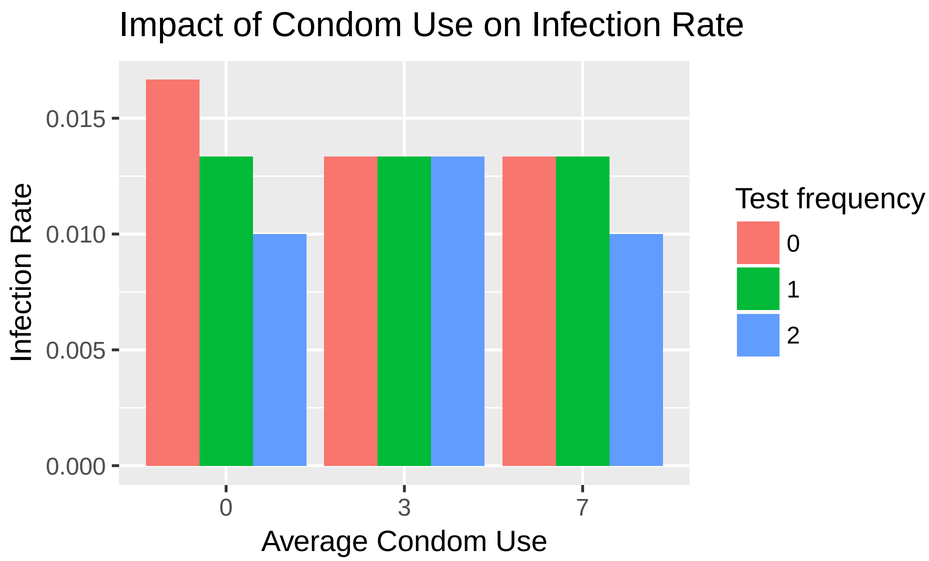
4 Results

We run 20 simulations over 7 years (365 ticks).

We looked at how infection rate varies based on different test frequencies for different average condom use. From the graph below, we see that, at an average test frequency of 1, condom use does not affect infection rate. However, if people don't get tested and don't use protection, the infection rate is higher at 1.67 % compared to 1.33% in the other instances, which represents a 25 % increase. However, the rate is still low. So, people who don't use protection and don't get tested have a higher infection risk. Overall, protection does not seem to cause much variation in infection rate as infection rate is more of less the same. However, those who get tested the most have a lower risk of infection whether they use protection or not.



We then looked at how infection rate varies based on different average condom use for different test frequency levels. We see that for people who don't use protection, getting tested is an important factor influencing infection risk. The more frequently the individual gets tested, the lower is risk of infection.



Based on the above diagrams we see that getting tested seems to be a more important factor in influencing infection risk.

The table below summarizes our results.

Table 3: Results

Type	Average Condom Use	Average Test Frequency	mean Infection Rate	median Infection Rate
With Education	7	2	0.0083	0.0083
With No Education	0	0	0.0092	0.01

We see that receiving sexual health education can lower infection rate by 9.78% based on the mean values. The median was 1% for those with no education and 0.83% for those with education.

Note that the current model used numbers associated generally with a college-aged population. Though our infection rates for the different approaches to education may seem minimal, they are reflected in the data from states such as California and Arkansas, discussed in the background. According to the CDC NCHHSTP Atlas Plus (2017), the average rate per 100,000 individuals of HIV prevalence in the 13-24 age group for 2015 was 3.7 for Arkansas, where sex education is not enforced, and the rate for California, who has a good sex education program, was 2 per 100,000 population. When adjusted to the small population in our model (300 college students) and the higher infected rate at the beginning, the expected rates for the different education policies are coherent. Florida, where sex education policies are more or less like that of Arkansas, had a rate of 5.1. We also made a conscious decision to start with 0.67 % of our sample infected, which is high, in order to see the difference in extreme policies, given our small sample size. However, our model reflects the overall average infection rate trend of education policies. Thus, based on our model, we conclude that sex education lowers risk of HIV infection. Fonner et al (2014) also concluded from their meta-analysis, that school-based sex education was effective in reducing HIV-related risk. Kirby DB, Laris BA, Rolleri LA. (2006) also reached similar conclusion.

5 Discussion

Based on our model we see that comprehensive sexual health education lowers HIV-related risk. People with no sexual health education have a higher HIV-infection risk. This conclusion resonates with reports from the CDC which led us to believe this model is a viable one.

To determine the values we set for average condom use and average test frequency, we looked for the optimal values during our exploratory data analysis phase. We wanted to show two extreme policies (Comprehensive Sexual Education program and no program) and their impact on HIV-infection risk. We also had a small population (300 agents) to work with and we decided to initialize the population with a .67% infected rate. These are why we ended up with an infected rate that is higher than that of the US on average. We thought this was the best option given our limitations.

We also had to make some assumption to simplify the model. We assumed that all sexual relationship carried more or less the same infection risk. However, the CDC has a comprehensive list of HIV Risk Behaviors and risks associated with each of them on its website (CDC, HIV Risk Behaviors) where different sexual behaviors exhibit different infection risk levels. So, one improvement in our model would be to consider the degrees of risky sexual interaction between couples. We also assumed that people of different ethnicities had the same infection risk. The CDC also publishes data on HIV prevalence and ethnicities. According to the data on its website, African-Americans account for a higher proportion of HIV cases as compared to other races (CDC, HIV Among African Americans). We could also consider ethnicities in our model.

While sexual health education programs alone may not be the most effective method to reduce HIV spread, they help in reducing infection risk. We believe our model captures the effect of sexual health education programs and the effect of its absence fairly well, given the limitations we faced. We recommend investing in sexual health education programs based on our findings. We also recommend to devote more resources on HIV testing, especially if limited resource is available. School programs should spend more resources in highlighting the importance of testing and make testing more accessible to students.

6 Reference

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